I-81 FREIGHT CAPACITY & CONNECTIONS:
PROVIDING OPPORTUNITIES FOR ECONOMIC GROWTH, EQUITABLE JOB ACCESS AND IMPROVED SAFETY

BENEFIT-COST ANALYSIS REPORT

FY2022 MPDG Application: INFRA & Rural

Washington County MARYLAND

MDOT MARYLAND DEPARTMENT OF TRANSPORTATION

Prepared for: Washington County, MD and Maryland Department of Transportation, State Highway Administration

May 23, 2022

Executive Summary

A benefit-cost analysis (BCA) was conducted for the **Interstate 81 Freight Capacity & Connections: Providing Opportunities for Economic Growth, Equitable Job Access and Improved Safety** Project ("the Project") for submission to the U.S. Department of Transportation (USDOT) as a requirement of a discretionary grant application for the Multimodal Project Discretionary Grant (MPDG) program. The analysis was conducted in accordance with the benefit-cost methodology as outlined by USDOT in the March 2022 (Revised) *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. The period of analysis is 2020-2048, and includes 9 past and future years of planning, design and construction, and 20 full years of benefits after operations begin in Summer of 2028.

The Project continues a multi-state effort to widen I-81 to better serve the freight and personal transportation needs of western Maryland and the Appalachian Region. Interstate travel on I-81 and I-70 today accounts for 50% of the vehicle miles traveled (VMT) in Washington County. The traffic along this critical area in the nation's supply chain is expected to grow, with an estimated 70% increase in freight tonnage over the next 20 years. The project area, as described in the application narrative, is home to a large and growing number of warehouses, manufacturing, and distribution facilities that depend on reliable Interstate access.

The Project represents an important investment in one of the most heavily utilized freight corridors in the United States. Only four lanes wide, the Maryland segment of I-81 carries freight volumes among the highest in the nation by lane mile, falling within the top 1% of all freight corridors. I-81 in the Project area today carries over 74,000 vehicles daily, approximately a quarter of which are trucks. This segment of I-81 has a high number and rate of crashes, and with only two lanes in each direction, crashes can result in hours-long traffic backups. The Project, as demonstrated below, will reduce crashes and crash-related delay, and provide improved reliability and reduced travel times for trucks and personal vehicles, ensuring interstate travel reliability for the future.

Costs

Capital Costs

Table 1 below shows the project expenses by year in uniform 2020 dollars. The costs of the Project, totaling $84.9 million, include costs related to right-of-way acquisition, utilities, engineering and design, and construction, and include funds already spent/committed on the project in past years.

At a 7% real discount rate, these costs are $57.0 million.

Table 1: Project Costs by Year, in Millions of Undiscounted 2020 Dollars

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	TOTAL
Project Costs	4.0	0.4	1.3	2.5	3.6	10.8	20.2	26.9	15.3	84.9

Source: Maryland Department of Transportation, 2022, converted to calendar years

O&M and Rehabilitation Costs

Annual operations and maintenance costs in the No-Build scenario are projected to average $165,640 in undiscounted 2020 dollars, compared to $236,340 in the Build scenario. The 15-year Rehabilitation and

Repair (R&R) work was estimated at $6.0 million for the No-Build and $6.6 million for the Build. Currently, in the No-Build, the R&R work is scheduled for 2025. The Project would move the R&R cycle forward to 2043. Over the entire analysis period, the net operations and maintenance costs total $16.3 million in undiscounted 2020 dollars (No Build), and $12.0 million (Build), representing a cost savings of $4.8 million when discounted at 7% following the recommendation of the current USDOT BCA Guidance.

Benefits

In 2020 dollars, the Project is expected to generate $61.4 million in discounted benefits using a 7% discount rate. The addition of lanes and other improvements to I-81 will reduce the number of crashes within the Project segment, reduce congestion due to road closures/crashes, and reduce congestion resulting from the current lack of capacity and high traffic volumes. The addition of a lane in each direction will also increase travel speeds, particularly during the peak hours, resulting in travel time benefits for all vehicles. The benefits lead to an overall Project Net Present Value of $4.3 million and a Benefit Cost Ratio (BCR) of 1.08.

The overall Project impacts can be seen in Table 2, which shows the magnitude of change and direction of the various impact categories.

Table 2: Project Impacts, Cumulative 2021-2046

Category	Unit	Quantity	Direction
Vehicle-Hours Traveled	VHT	2,877,587	▼
Fatalities	#	2.5	▼
Injury Crashes	#	290	▼
Property Damage Only (PDO)	#	484	▼

Source: CCI Engineering Services (CCI), 2022

The Project benefit matrix can be seen in on the following page, providing more detail on the sources and recipients of the benefits quantified in the tables above.

Table 3: Project Impacts and Benefits Summary, Monetary Values in Millions of 2020 Dollars

Baseline & Problem to be Addressed	Change to Baseline	Type of Impact	Population Affected by Impact	Summary of Results (at 7% disc. rate)	Page Reference in BCA
Traffic congestion in the Project area results in slower average speeds and reduced vehicle throughput for business, personal and freight travel	Adding lanes reduces bottlenecks, increase throughput, improving speeds	Travel Time Savings	Auto & Freight	$20.0m	p10
Capacity constraints make lane closures from crashes (and other events) result in major traffic backups					
Congestion and merging traffic results in frequent sideswipe and rear-end collisions	The additional lane in the I-81 Highway mainline reduces dangerous weaving conditions	Crash Reduction	Auto & Freight, General Society	$36.5m	p13
Need for Rehabilitation on Project segment of I-81	Reconstruction project will eliminate need for rehabilitation work due in 2025 on existing (value at right is reduced by addl costs of maintaining 6 vs 4 lanes)	State of Good Repair	Auto & Freight	$4.8	p7 and 8

Source: CCI, 2022

Contents

1 Introduction

A benefit-cost analysis (BCA) was conducted for the **Interstate 81 Freight Capacity & Connections: Providing Opportunities for Economic Growth, Equitable Job Access and Improved Safety** Project ("the Project") for submission to the U.S. Department of Transportation (USDOT) as a requirement of a discretionary grant application for the MPDG program.

The following sub-sections describe the BCA framework, evaluation metrics, and report contents.

1.1 BCA Framework

A BCA is an evaluation framework to assess the economic advantages (benefits) and disadvantages (costs) of an investment alternative. Benefits and costs are quantified in monetary terms to the extent possible. The overall goal of a BCA is to assess whether the expected benefits of a project justify the costs from a national perspective. A BCA framework attempts to capture the net welfare change created by a project, including cost savings and increases in welfare (benefits), as well as disbenefits where costs can be identified (e.g., project capital costs), and welfare reductions where some groups are expected to be made worse off because of the proposed project.

The BCA framework involves defining a Base Case or "No Build" Case, which is compared to the "Build" Case, where the grant request is awarded and the project is built as proposed. The BCA assesses the incremental difference between the Base Case and the Build Case, which represents the net change in welfare, or benefit. BCAs are forward-looking exercises which seek to assess the incremental change in welfare over a project lifecycle. The values of future welfare changes are determined through discounting, which is meant to reflect both the opportunity cost of capital as well as the societal preference for the present.

The analysis was conducted in accordance with the benefit-cost methodology as recommended by USDOT in the March 2022 (Revised) *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*.

The analysis methodology includes the following:

- Defining existing and future conditions under a No Build base case as well as under the Build Case
- Estimating benefits and costs during project construction and operation, including 20 years of operations beyond the Project completion
    - This included Traffic Simulation Analysis (performed by MDOT) to determine VHT and traffic volumes for the No Build and Build for 2030 and 2045.
- Applying USDOT-recommended monetized values for reduced fatalities, injuries, property damage
- Applying MDOT recommended values for travel time benefits
- Converting costs to real 2020 dollars. In instances where cost estimates and benefits valuations are expressed in historical or future dollar years, using an appropriate inflation factor to adjust the values
- Discounting future benefits and costs with real discount rates of 7% consistent with USDOT guidance

1.2 Report Contents

Section 2 contains an explanation of the benefit-cost analysis methodology and a description of the project. Section 3 contains a detailed explanation and calculation of the project costs. Section 4 contains a detailed explanation and calculation of the benefit categories. Section 5 contains the detailed results of the benefit-cost analysis.

2 Project Overview

2.1 Description

The Maryland Department of Transportation State Highway Administration (MDOT SHA), in partnership with Washington County, Maryland, is requesting $65.04 million (80%) in US DOT Multimodal Project Discretionary Grant (MPDG) funding under both the INFRA and Rural Transportation programs, to complete the I-81 Freight Capacity & Connections Project. The Project will significantly improve safety and operations, while also providing opportunities for economic growth and equitable job access along 3.5 miles of I-81 in Western Maryland. When funded, this Project will complete Phase 2 of a larger multi-phase, multi-state project to expand I-81 within the State of Maryland (see Figure below).

One of the Nation's Freight Backbones: *I-81 is essential to moving freight from Canada to Tennessee. Thousands of regional jobs in MD, WV, and PA are dependent on I-81 moving freight through Western Maryland.*

2.1.1 *I-81 Background and Importance*

I-81 is a continuous north-south highway extending from Canada to Tennessee, designated as a major freight corridor on the National Highway Freight Network. I-81 links Virginia, West Virginia, Maryland, and Pennsylvania, and is heavily used as a long-distance truck bypass around the congestion of I-95 and other coastal routes, delivering freight throughout the state and region. The corridor serves freight traffic between Origins and Destinations along the East Coast, and west towards Texas, Iowa, and Louisiana. This highway is also part of the Strategic Highways Network, as it has been identified as critical to the Department of Defense's domestic operations, emergency mobilization, and peacetime operations. Due to its proximity to Washington, DC, and other major metropolitan areas along the East Coast, this corridor's ability to handle emergency evacuations due to natural disasters or other events underscores its importance.

I-81 Improvement Project Phasing

As described in the application narrative, I-81 is vital for the distribution of raw materials and finished goods between Appalachia and some of the largest consumer markets in the Northeast. Several major North American distribution facilities are located near the I-81 project segment, including Tractor Supply Company, Sealy Mattress, FedEx, Home Depot, Fives Landis, an Amazon fulfillment center, along with other manufacturing, warehousing and distribution centers. Freight traffic within the I-81

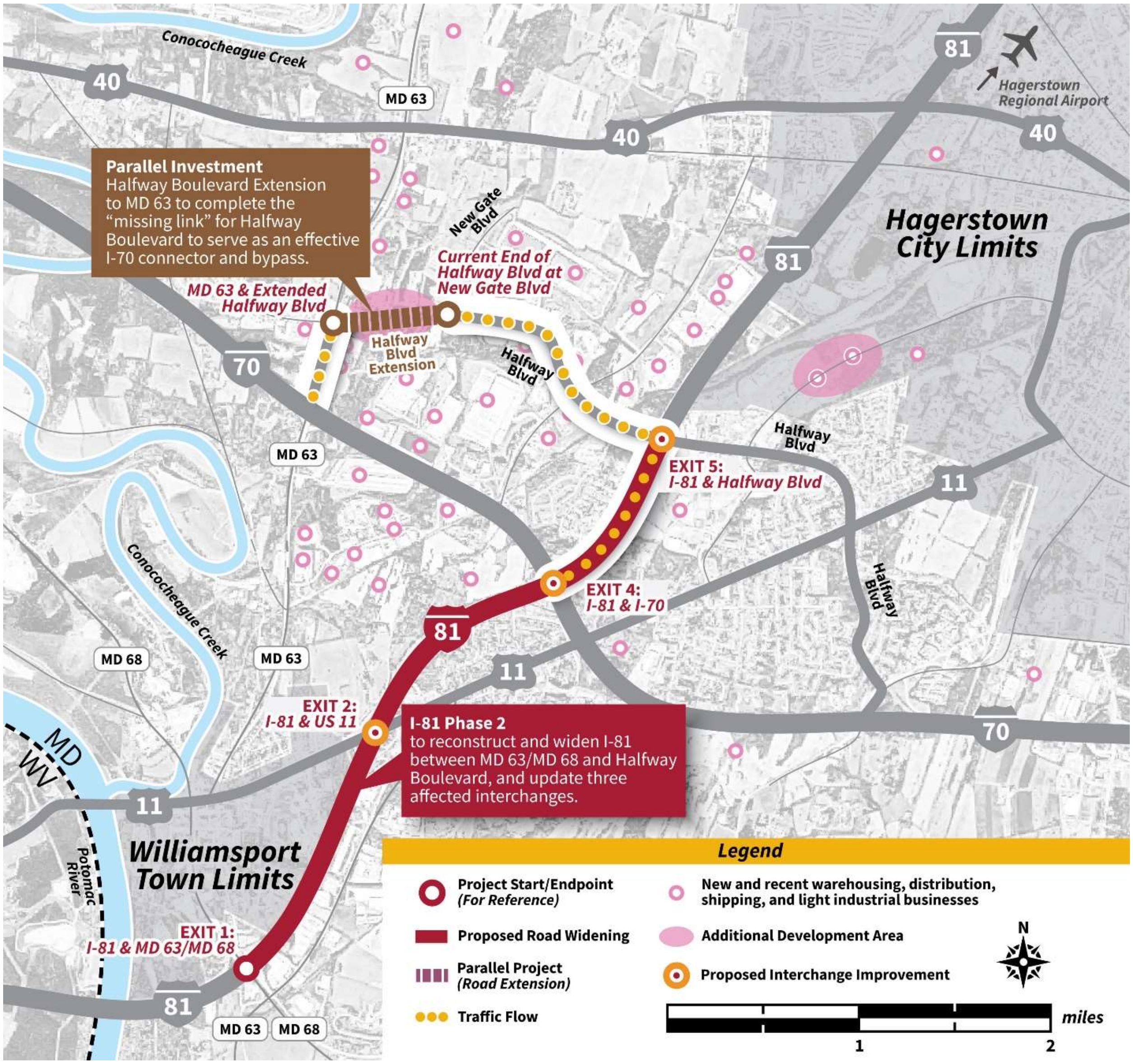
Project segment has grown substantially in the five-decade period since its construction, however the highway itself has remained substantively unchanged. Consequently, connectivity, safety, and traffic flow have suffered.

2.1.2 *Project Scope*

The Project will improve safety and traffic operations along 3.5 miles of I-81 from 2,000 feet north of MD 63/MD 68 to 1,000 feet north of the Halfway Boulevard interchange. A map of the project segment is shown in the map on the following page. This includes widening the interstate from four to six through lanes, with the construction of two new travel lanes (one southbound and one northbound). The Project also improves ramp and merge lane configurations for three interchanges, including the critical interchange connecting I-70 and I-81. Project improvements will dramatically reduce the crash rate on a segment of I-81 marked by high freight traffic levels and a troubling safety history. The Project will also:

- Improve the interchange with I-70.
- Deploy ITS devices such as dynamic message signs (DMS), automatic traffic recorders, and software enhancements that enhance wayfinding and help reroute traffic in real time.
- Implement stormwater management improvements and install noise barriers as required.
- Install electric vehicle (EV) chargers at two locations to support and encourage expanded EV truck fleets and other EVs.

This Project has been a priority for the state for several decades, and represents one of MDOT SHA's largest investments in Western Maryland.



Project Context

2.2 General Assumptions

2.2.1 *Evaluation Period*

The period of analysis used for this BCA is 2020-2048, and includes past/current/future years of planning, design and construction (2020-2028), and 20 full years of benefits after operations begin in Summer of 2028 (that is, 2029-2048).

For the purposes of this study, it is assumed that the environmental services and other work on the project began in 2020, with construction to be completed by 2028, and operations beginning midway through 2028. As such, the 20-year evaluation period concludes after 20 *full* years of operation, ending in 2048.

2.2.2 *Discount Rates and Dollar Values*

For project costs and benefits, monetary values in this analysis are expressed in constant 2020 dollars. In instances where certain cost estimates or benefit valuations were expressed in dollar values from 2019, the conversion factor was taken from Table A-7 of the BCA Guidance. Where values were from 2021 or 2022, the U.S. Bureau of Labor Statistics' CPI Inflation Calculator was used to adjust them to 2020 prices (https://www.bls.gov/data/inflation_calculator.htm).

The real discount rate used for this analysis is 7.0%, consistent with USDOT guidance for Discretionary Grant Programs and OMB Circular A-4.

2.3 Base Case and Build Case

The analysis considers how the balance of costs and benefits resulting from the proposed Project improvements would result in long-term benefits to its users and general society, compared to a future without the Project.

In the "Build" Case, the Project includes the expansion of Interstate 81 from four lanes to six lanes between the US 11 and Halfway Boulevard interchanges, as well as interchange modernization of the three interchanges in this segment. The expansion of the highway will include an additional through lane in each direction of travel.

The "No Build" Case examines the societal costs of not implementing these Project improvements, while traffic continues to increase, resulting in additional crashes, increased traffic delays, increased damage to the existing highway infrastructure, and increased costs for vehicles.

3 Project Costs

3.1 Capital Costs

The grant application narrative uses a figure of $81.3 million for total project costs. The BCA includes and additional $10.5 million in previously spent or committed preliminary engineering and other Project costs. Table 4 below shows the expenses by year in uniform 2020 dollars. The costs of the Project, totalling $84.9 million, include costs related to right-of-way acquisition, utilities, engineering and design, and construction.

At a 7% real discount rate, these costs are $57.0 million.

Table 4: Project Costs by Year, in Millions of Undiscounted 2020 Dollars

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	TOTAL
Project Costs	4.0	0.4	1.3	2.5	3.6	10.8	20.2	26.9	15.3	84.9

Source: MDOT 2022, converted to calendar years

3.2 Operations and Maintenance Costs

Annual operations and maintenance (O&M) costs in the (4-lane) No-Build scenario are projected to average $165,640 in undiscounted 2020 dollars, compared to $236,340 in the (6-lane) Build scenario. This is based on MDOT estimates done in 2021, escalated from 2019 to 2020 dollars using the factors in Table A-7 of the USDOT BCA Guidance.

The "No Build" case includes the operating and maintenance costs of the four existing highway lanes and the highway shoulders.

In the "Build" Case, the operations and maintenance costs include the patching and resurfacing of the four existing highway lanes, the two new highway lanes, and the highway shoulders. During the construction years, it is assumed that O&M costs would be half of what those in the No Build, because much of the necessary O&M would be covered as part of the project construction. O&M Costs during the design work are assumed to be the same as the No Build.

The resulting operations and maintenance costs for the "Build" and the "No Build" Case for the Project segment are shown in Table 5. The net O&M cost savings throughout the analysis period are negative, representing a cost of $254,063 when discounted using a 7% rate. Per USDOT guidance, these net O&M costs are included as a benefit in the numerator of the benefit-cost equation.

Table 5: Operations and Maintenance Costs (in 2020 Dollars)

	No-Build	**Build**	**Net Change Benefit/(Cost)**
Annual Cost	$165,640	$236,340	($70,700)
Total 2022-2048 (Undiscounted)	$4,306,640	$5,389,360	($1,082,720)
Total 2022-2048 (Discounted)	$2,	$2,392,748	($254,063)

Source: CCI, 2022

3.3 Repair and Rehabilitation (R&R) Costs

The I-81 lanes need to be rehabilitated every 15 years, per MDOT's standard practices. Because the Project includes resurfacing of existing lanes, the R&R cost in the Build will occur 15 years after construction, in 2043. The "No Build" Case will require R&R work on the existing lanes in 2025, and then in 15-year increments thereafter, starting in 2040.

In 2022, MDOT estimated the cost of R&R for the No-Build at $6.0 million in 2020 dollars, and the cost of R&R for the Build at $6.6 million.

Table 6: Rehabilitation Costs over the 2022-2048 analysis period (in 2020 Dollars)

	No-Build	**Build**	**Net Change Benefit/(Cost)**
Annual Cost in 2020$	$6,000,000	$6,600,000	($600,000)
Total 2022-2048 (Undiscounted)	$12,000,000	$6,600,000	$5,400,000
Total 2022-2048 (Discounted)	$6,672,971	$1,593,986	$5,078,984

Source: Maryland Department of Transportation & CCI, 2022

Net R&R cost savings throughout the analysis period were calculated at $5.1 million in 2020 dollars, discounted using a 7% rate.

4 Project Benefits

This Project will increase the economic competitiveness of the nation and the study area through improvements in the mobility of people and goods on I-81. The quantified benefits occur in two categories: user benefits (travel time savings) and social benefits (reduced damage to property and people resulting from crashes).

The analysis quantified the following benefit categories (Table 7):

Table 1: Project Benefits by Category in Millions of Discounted 2020 Dollars

Type of Benefit	Description	Monetized
Travel Time Savings	Elimination of bottlenecks in the freight supply chain; time savings in commute and business travel in the Mid-Atlantic region	$20.0m
Safety	Reduction in crashes, including fatalities, injuries & property damage, in the Interstate 81 corridor	$36.5m

The sections below describe the inputs used in developing the estimate of Travel Time Savings and Crash Reduction, beginning with the travel demand model results used for both of these calculations.

4.1 Travel Model Projections and Traffic Analysis

The Maryland Statewide Transportation Model (MSTM) uses existing and future land use, population, employment, and other data to forecast future volume and freight volumes throughout the corridor and along adjacent roadways. The MSTM growth rates are applied to recent traffic volumes along the corridor to calculate existing and future traffic volumes. The existing and future volumes are inputs for the traffic stimulation analysis software. For this BCA, four scenarios were developed:

- 2030 No Build
- 2030 Build
- 2045 No Build
- 2045 Build

Some of the outputs from the traffic analysis are shown in the tables below. The traffic volume numbers shown in Table 8 were used to calculate the traffic growth rates in Table 9, which in turn were used for calculating the growth in safety benefits.

Table 8: Average Daily Traffic

Roadway Section	2021 Existing	2030 No-Build	2030 Build	2045 No-Build	2045 Build
MD 68 to I-70	64,300	70,375	70,750	80,500	81,500
I-70 to US 40	74,600	80,450	80,875	90,200	91,300
Average	69,450	75,413	75,813	85,350	86,400

Source: MDOT, 2022

Table 9: Traffic Growth Rates

Period	Period Growth	Annualized Growth
2021-2030 No Build	8.6%	0.92%
2021-2030 Build	9.2%	0.98%
2030-2045 No-Build	13.2%	0.83%
2030-2045 Build	14.0%	0.88%

Source: CCI 2020, calculated from MDOT model outputs

4.2 Value of Travel Time on I-81 through the Project Area

Value of travel time varies depending on the percentage of trucks in the traffic flow. The MSTM forecasts a 24% truck share for both 2030 and 2045 on the Project segment of I-81.

For the value of Travel Time, this BCA follows the guidance provided in the June 2021 Update of the *MDOT Loss of Public Benefit (LOPB) Spreadsheet User Guide*, which recommends an hourly value of time of $25.50 for Autos and $30.75 for Trucks (in 2020 dollars). Using these rates, a traffic flow of 24% trucks and 76% autos yields a Project-specific average value of travel time of $26.74 per hour in 2020 dollars.

The MDOT LOPB is attached as an appendix to this document.

4.3 Travel Delay Reductions

Reductions in vehicle hours traveled (VHT) are expected from two different Project effects:

- Avoided crash-related delay – there is currently a high number of crashes on I-81 in the Project area, with approximately 20% involving trucks. When a crash blocks one or both of the two lanes (either northbound or southbound), the traffic backlog can last for hours, involving thousands of vehicles.
- Travel time savings on I-81 – resulting from the increased capacity of adding one lane in each direction, as well as traffic operation benefits from interchange upgrades.

Reduced hours of travel are often called travel time savings or avoided delay.

The AM and PM weekday delay was analyzed for each of the four scenarios. The calculations of the annual figures are shown in Table 10, and explained below.

1. The difference between the No-Build and Build scenarios was calculated for the AM Peak and the PM Peak VHT, and then summed to create the “Sub-total” peak hour savings.
2. Following MDOT’s recommended methodology, these base figures for the two modeled years (2030 and 2045) were then multiplied by 3.0 to account for the “peak shoulders” – the hours typically surrounding the single peak hour where traffic congestion is less than during the Peak hour, but still causing delay.
3. The resulting weekday daily figures were then multiplied by 250 to generate an estimate of annual delay (using 250 instead of 365 days per year accounts for lower congestion on weekend days and holidays).

Table 10: Peak Hour Travel Delay Reduction (No-Build vs Build)

Roadway Section	2030 AM Peak	2030 PM Peak	2045 AM Peak	2045 PM Peak
No-Build Delay	246 hours	473 hours	648 hours	1,078 hours
Build Delay	246 hours	453 hours	624 hours	1,021 hours
VHT Savings	0 hours	20 hours	24 hours	57 hours
Sub-total Peak Hour Savings	20 hours		81 hours	
Total Daily VHT Savings (x3.0)	60 hours		243 hours	
Annual Recurrent VHT Savings (x250)	15,000 hours		60,546 hours	
Annual Non-Recurrent Delay Savings (x2.5)	37,500 hours		151,365 hours	
TOTAL Annual Delay Savings	52,500 hours		211,911 hours	
Value per Hour	$26.74		$26.74	
Annual Value of VHT Savings	**$1,403,798**		**$5,666,270**	

Source: MDOT model, 2022

4. MDOT's recommended factor for estimating delay due to "non-recurrent" factors, such as crashes, is 2.5. The derivation and justification of this number is explained in the text box on the following page. However, it may be a bit conservative as this factor does not account for the substantial reduction in crashes expected with the Project improvements.
5. The recurring and non-recurring VHT savings were summed to create a total VHT benefit for 2030 and for 2045. Multiplied by the value-per-hour figure explained above in Section 4.2, the value of travel time savings in 2030 was estimated at $1,403,798, and $5,666,270 for 2045.

The VHT for the other years in the BCA calculations were derived using straight-line growth, specifically:

Yearly growth in VHT savings

= [(the difference between the 2045 and 2030 VHT savings) divided by 15].

Based on these assumptions, the total reduction in travel time for the Project is calculated to be worth $20.0 million in discounted 2020 dollars

Recurring and Non-Recurring Congestion

Congestion can be categorized into two broad types.

Recurring congestion is congestion that occurs on a regular basis as a result of typical traffic demand, usually during the weekday morning and afternoon rush hours. The operational impacts of recurring congestion can be evaluated by determining the existing AM and PM peak hour demand, forecasting future peak hour volumes for a horizon year based on a projected growth rate from regional demand models, and analyzing the projected operations of the roadway using traffic analysis tools, such as Highway Capacity Software, and/or microsimulation tools such as VISSIM.

Non-recurring congestion refers to travel delays that occur during off-peak hours typically due to factors other than high traffic demand. This could include incidents, weather, and work zones that temporarily limit the capacity of the roadway facility. It could also include congestion related to temporary spikes in demand due to special events or holidays. Non-recurring congestion is typically more difficult to forecast because it is hard to predict the number of incidents, work zones, and weather events that a corridor will experience 20 to 25 years in advance. Also, in many areas, the impacts of recurring congestion far outweigh the impacts of non-recurring congestion. Therefore, non-recurring congestion is sometimes ignored when evaluating transportation projects.

However, in the case of I-81 in Maryland, non-recurring congestion is a significant source of the overall congestion experienced along the corridor throughout the year, and was therefore an important component of the overall evaluation. This can be attributed to several factors, including a high truck percentage along the corridor and the location's susceptibility to winter storms.

To estimate future non-recurring congestion impacts, the project team reviewed comprehensive speed and travel time data from INRIX for the entire calendar year of 2021 along the I-81 corridor. Delays that occurred during the weekday peak periods (6am to 9am and 3pm to 6pm) were classified as recurring congestion, while delays that occurred during the other 18 weekday hours or on the weekend were classified as non-recurring congestion. The results showed that the total number of vehicle-hours of delay experienced during the off-peak times was approximately **2.5 times greater** than the total number of vehicle-hours of delay experienced during the weekday peak times over the course of the year.

The additional capacity provided by the I-81 Phase 2 Widening project is projected to significantly reduce both the recurring and non-recurring congestion experienced along the corridor. The operational benefits during the peak hours were projected by comparing the No Build and Build vehicle-hours of delay from VISSIM models developed for the AM and PM peak periods. Then, the benefits to non-recurring congestion were estimated by applying a factor of 2.5 to the recurring congestion results, consistent with the ratio of non-recurring to recurring congestion observed along the corridor in 2021. The total operational benefits were calculated by adding the savings related to both recurring and non-recurring congestion.

Source: MDOT, 2022

4.4 Safety

The safety benefits assessed in this analysis include a reduction in fatalities and injuries, as well as a reduction in property damage crash costs resulting directly from the Project.

The relatively high volume of freight trucks as a percentage of the total traffic volume in the I-81 corridor, and the high rates of crash incidents within the 3.5-mile Project segment result in significant interruptions to the delivery of goods, as well as damage to property and people. With high traffic volumes limited to two lanes in each direction, combined with closely-spaced interchanges creating weaving movements, incidents involving trucks and passenger vehicles occur regularly. From 2015 to 2019, 640 crashes occurred within the 3.5-mile Project segment, including 239 injuries and two fatalities. The expansion of the highway allows for an improved separation of truck and passenger vehicles and reduced collisions between drivers, resulting in a projected 26% reduction in crashes and delay-causing incidents, or 775 fewer crashes over the benefit period.

The projected decrease in crashes is based on the MDOT I-81 Phase 2 Safety Analysis Study. Historically, the rate used in the BCA for this Project was based on a 40% reduction in crashes – a number approved by USDOT in a de-brief call regarding a previous grant application BCA for I-81 Phase 2. The previous analysis applied the full 80% reduction in crashes that was experienced on a recent widening of the West Virginia segment of I-81, which was improved just a mile to the south of I-81 Phase 2. That segment saw an 80% drop in crashes comparing the four years prior to the 4-to-6 lane expansion, to the four years after the widening was opened to traffic. It was felt to be more conservative to assume a 26% reduction based on the crash modification factor related to constructing an additional highway lane ("Install an Additional Lane", CMF ID: 8336).

The dollar cost of baseline crash levels was assessed using 2015-2019 data, shown in Table 11 below. These reflect pre-COVID rates, which are presumably more relevant to the post-construction period being examined by this BCA than data from the height of the pandemic in 2020. Maryland crash data for 2021 is still preliminary.

Table 11: Project Area Crashes by Type, 2015-2019

Crash Type	2015	2016	2017	2018	2019	Total	Annual Average
Fatalities	0	1	1	0	0	**2**	**0.4**
Injuries	58	58	45	55	23	**239**	**47.8**
Property Damage Only	61	78	113	111	36	**399**	**79.8**
Total Crashes	**119**	**137**	**159**	**166**	**59**	**640**	**128**

Source: MDOT

Table 12 below shows the value of crash types from the USDOT BCA Guidance, and how these add up to a current average cost of crashes of $19.9 million in 2020 dollars (undiscounted).

This annual figure was grown by the No-Build traffic growth factors listed above in Table 9 – specifically, 0.92% per year for 2022-2030, and 0.83% per year for beyond 2030. The slightly lower No-Build factors were used instead of the Build growth factors, to be conservative.

As the table below shows, the resulting value of the expected crash reduction over the course of the analysis is $36.5 million in discounted 2020 dollars, representing more than half of total project benefits.

Table 22: Estimation of Safety Benefits

Benefit	2015-2019			Project Lifecycle		
	Average Crashes per Year (2015-2019)	**Value by Crash Type (2020$)**	**Total Cost of Crashes (2020$)**	**Crashes Avoided**	**Undiscounted Value** (millions of 2020$)	**Discounted (7%)** (millions of 2020$)
Fatalities	0.4	$12,837,400	$5,134,960	2.5	$31.1	$9.4
Injuries	47.8	$302,600	$14,464,280	290	$87.7	$26.6
Property Damage Only	79.8	$3,900	$311,220	483	$1.9	$0.6
Total	**128**	**$4.1**	**$19,910,460**	**775**	**$120.7**	**$36.5**

Source of Crashes: MDOT

Source of Crash Values: 2022 USDOT BCA Guidance, Table A-1

Calculations: CCI, 2022

5 Summary of Results

5.1 Evaluation Measures

The benefit-cost analysis converts potential gains (benefits) and losses (costs) from the Project into monetary units and compares them. The following common benefit-cost evaluation measures are included in this BCA:

- Net Present Value (NPV): NPV compares the net benefits (benefits minus costs) after being discounted to present values using the real discount rate assumption. The NPV provides a perspective on the overall dollar magnitude of cash flows over time, expressed in today's terms.
- Benefit Cost Ratio (BCR): The evaluation also estimates the benefit-cost ratio. The present value of incremental benefits is divided by the present value of incremental costs to yield the benefit-cost ratio. The BCR expresses the relation of discounted benefits to discounted costs as a measure of the extent to which a project's benefits either exceed or fall short of the costs.

5.2 BCA Results

The table below presents the evaluation results for the Project. Results are presented both undiscounted, and discounted at 7%, as prescribed by the USDOT. All benefits and costs were estimated in constant 2020 dollars over an evaluation period extending 20 full calendar years beyond the completion of construction.

The total benefits from the Project improvements within the analysis period are calculated to be $61.4 million in discounted 2020 dollars. The total capital costs, including engineering, construction, utilities, and right-of-way and land acquisition, are calculated to be $57.0 million in discounted 2020 dollars. The difference of the discounted benefits and costs equal a net present value of $4.3 million, resulting in a benefit-cost ratio (BCR) of 1.08.

Table 3: Benefit Cost Analysis Results, 2020 Dollars

Benefit/Cost Metric	Undiscounted Costs	Discounted Costs at 7%
Capital Costs	**$ 84,922,677**	**$ 57,039,823**
Benefits		
Reduced O&M and R&R costs	$ 4,317,280	$ 4,824,921
VHT Benefits	$ 76,943,787	$ 20,048,217
Safety Benefits	$ 120,723,943	$ 36,548,889
Total Benefits	**$ 201,985,010**	**$ 61,422,027**
Net Benefits	**$ 117,062,333**	**$4,382,204**
Benefit/Cost Ratio	**2.38**	**1.08**

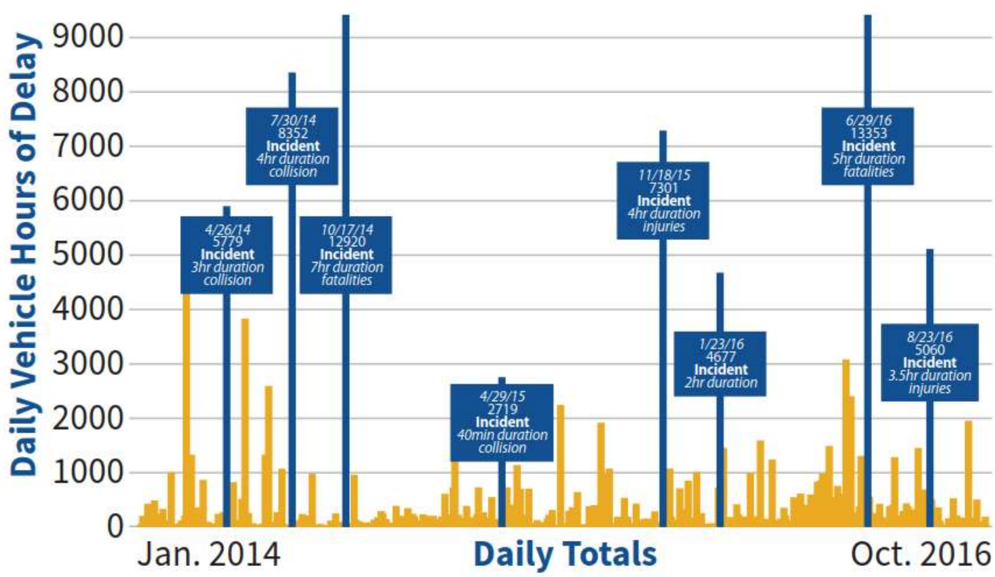
Source: CCI, 2022

5.3 Non-Quantified Benefits

There are a number of Project benefits that could not be reasonably quantified for the Benefit-Cost Analysis, or were left out to be conservative. Among these are:

- Avoided pavement damage currently experienced from trucks diverting to local roads to avoid backups on I-81
- Emissions benefits from the new EV charging stations being implemented as part of this project
- Emissions and travel time benefits from the IT infrastructure that will allow drivers to avoid congestion
- Reduced emissions: with an additional lane in each direction, the backups caused by a blocked lane will be greatly reduced, decreasing emissions from slow speeds and idling. Recent data was unavailable to reasonably quantify this benefit.

  However, as an example of the potential scale of these benefits, the Figure below presents an analysis that was done for 2014-2016 incidents showing 14 separate incidents, each with over 2,000 vehicle hours of delay. As the graphic below illustrates, two incidents exceeded 12,000 vehicle hours of delay. While the travel time benefit of avoiding these crashes is included in the BCA (see discussion on "non-recurring travel delay" in Section 4.3 above), an estimate of the benefit of emissions reductions was not able to be included.



INRIX daily vehicle hours of delay and major crashes on Maryland Interstate 81

Source: MDOT

Appendix

MDOT SHA Loss of Public Benefit (LOPB) Spreadsheet User Guide

June 2021 Update

MDOT SHA Loss of Public Benefit (LOPB) Spreadsheet User Guide
June 2021 Update

Quick Guide

A. INTRODUCTION

What is Loss of Public Benefit?

The Loss of Public Benefit (LOPB), also known as User Costs, is the cost that motorists incur during construction of a project. These costs are typically assumed to consist of quantifiable items such as travel time costs, increased fuel costs due to longer distances traveled or worsened operations through a work zone area, additional wear and tear on vehicles, and safety disbenefits. LOPB can be used to quantify the costs to the public due to the late completion of a construction project phase, or the value gained by the early completion of a project.

LOPB costs are included within the sections of construction contracts which cover scheduling issues. Typical uses of LOPB costs by transportation agencies, such as MDOT SHA, include calculation of incentive/disincentive clauses in construction contracts to reward the contractor for finishing a project early or to provide incentive not to finish beyond an agreed to completion date. Another typical use is to calculate a penalty if temporary lane closures during construction extend beyond approved time of day restrictions (such as nighttime closures extending into the morning rush hour). Depending on the policies of the transportation agency, these costs may be calculated on a project-by-project basis using site-specific traffic and geometric information, or average costs may be developed which are applied to a number of projects.

Why has MDOT SHA created this program and who are the intended users?

To calculate these costs, many transportation agencies across the United States have developed their own methodologies to account for the cost factors listed above. There is no standard process or program that is used by all states. The purpose for MDOT SHA to develop this particular tool was to create a program which would produce consistent results among a variety of different users, would use current and local available transportation data and trends (as well as information that can continue to be updated over time), and uses a compilation of methodologies and data sources that are being used successfully by others.

The primary intended users for this program include the staff and consultants of MDOT SHA's Travel Forecasting and Analysis Division (TFAD) in the Office of Planning and Preliminary Engineering (OPPE). Typically, TFAD is requested to provide this information for upcoming MDOT SHA construction projects to be included in the contract language for incentive/disincentive clauses. The program may also be of assistance to MDOT SHA's Office of Traffic and Safety (OOTS), who often provide input into lane closure fees for projects.

How was this program developed?

In preparation for the development of this program, the program development team researched a variety of sources to determine what would be the appropriate methodologies and data sources to use within the program. A review of published information from government, private, and academic sources was undertaken; other state transportation agencies were surveyed regarding their current practices; and several commercially and publicly available software packages were reviewed. This information was condensed into recommendations for procedures and data sets which were presented to TFAD and OOTS staff to receive their input on the appropriateness of the proposed program's direction. The tool was updated in 2020 to switch to a more stable Microsoft Excel-based format, improve calculation methodologies, and update wage and cost data.

B. COST VALUES, DATA SOURCES, AND CALCULATIONS

Costs incurred by motorists as a result of roadway construction are generally broken down into three primary categories: delay costs, operating costs, and crash costs. Delay costs quantify the value of the amount of additional travel time required for road users to make their trip while a project is under construction, either due to traffic congestion within or approaching the work zone, or due to following a signed detour route. Operating costs refer to the value of additional fuel consumption and wear-and-tear on the vehicle caused by the work zone, either due to traveling an increased distance on a detour route, experiencing increased stops on a detour route, or idling in a queue caused by the work zone. Crash costs are related to the financial implications of crashes in the work zone or in the existing roadway segment before the improvement is constructed. This section discusses the values for delay costs, operating costs, and crash costs used in MDOT SHA's LOPB Spreadsheet.

Delay Costs

Calculating the total delay cost associated with a construction project requires multiplying the additional travel time by each road user's estimated value of time. The amount of additional travel time will vary depending on the type and magnitude of project, as discussed later in this user guide in Section C. This subsection discusses MDOT SHA's methodology for calculating the average value of time for road users to be used in delay cost calculations.

Value of time (VOT) is categorized as automobile VOT and truck VOT, which are calculated using the methodology presented in the September 2010 American Association of State Highway and Transportation Officials (AASHTO) publication, *User and Non-User Benefit Analysis for Highways*, commonly referred to as the AASHTO "Red Book."

Based on available research data, Chapter 5 of the Red Book recommends using **Equation 1** below to calculate automobile VOT as a function of the average wage rate:

Equation 1: $VOT_{auto} = Average\ wage\ rate\ \times Wage\ rate\ percentage\ \times Average\ automobile\ occupancy$

The VOT is first calculated with the most recently available wage rate data and is then adjusted to the present year. The most recently available average wage rate for the state of Maryland from the Bureau of Labor Statistics (BLS) was $30.58 per hour as of May 2020. The Red Book indicates that the perceived value of time for personal local trips and the drive-alone commute for each road user is approximately 50% of their wage rate. For simplicity of calculations, it is assumed that these two trip purposes comprise the majority of road users through the work zone, and therefore a value of 50% is utilized in the equation. The final variable is the average automobile occupancy. Based on data from the 2017 National Household Travel Survey, the most recent available source of information, the national average automobile occupancy is approximately 1.67 persons per vehicle. Substituting these values into **Equation 1** yields an average value of time for automobiles in Maryland of approximately \$25.50 per hour, rounded to the nearest quarter in year 2020 dollars.

$$VOT_{auto,2020} = \$30.58 \times 50\% \times 1.67 = \$25.53 \approx \$25.50/\mathrm{hr}$$

The automobile VOT should use the most recently available data. However, because wage rate data is typically at least one year old upon release, the Urban Consumer Price Index of All Items (CPI-U, All Items) is applied to adjust wage rate data to the present year. As mentioned earlier, the most recent wage rate data available at the time of the LOPB Spreadsheet development was from May 2020. Therefore, the automobile average wage rate used in analyses is adjusted to the present year using the CPI-U, All Items of the base year (2020) and present year as shown in **Equation 2** below:

Equation 2: $VOT_{auto,\,present} = VOT_{auto,\,base} \times \frac{\textit{CPI-U, All Items}_{present}}{\textit{CPI-U, All Items}_{base}}$

The CPI-U, All Items in May 2020 used in the LOPB Spreadsheet was 256.394. As an example, the automobile VOT for April 2021 (CPI-U, All Items of 267.054) would be calculated using **Equation 2** as:

$$VOT_{auto,\ April\ 2021} = \$25.50 \times \frac{267.054}{256.394} = \$26.56/\mathrm{hr}$$

The truck VOT calculation process is the same as the auto VOT process where the base year VOT is calculated and then adjusted to the present year VOT using the ratio of CPI-U, All Items. The Red Book recommends a similar equation for calculating truck VOT; however, it is a function of the average total compensation for the truck drivers rather than the average wage rate as shown in **Equation 3** below:

Equation 3: $VOT_{truck} = Average\ compensation\ rate\ \times Average\ truck\ occupancy$

The average compensation rate for truck drivers in Maryland was calculated using the average wage rate for truck drivers and an additional compensation percentage. According to May 2020 BLS data, the average Maryland truck driver wage rate was \$24.08 per hour. This value was converted to the average compensation rate using a calculated average additional compensation percentage of 25% for truck drivers in Maryland, calculated from the Bureau of Economic Analysis (BEA) website by dividing the Compensation of Employees Industry by the Wages and Salaries. An average vehicle occupancy rate of 1.02 persons per truck was used based on a 2013 Highway Economics Requirements System (HERS) report. Inserting these values into **Equation 3** yields an average truck VOT of approximately \$30.75 per hour, rounded to the nearest quarter in year 2020 dollars.

$$VOT_{truck,2020} = [\$24.08 \times (1 + 25\%)] \times 1.02 = \$30.70 \approx 30.75/\mathrm{hr}$$

The truck VOT is adjusted to the present year as shown in **Equation 4**.

Equation 4: $VOT_{truck,\,present} = VOT_{truck,\,base} \times \frac{\textit{CPI-U, All Items}_{present}}{\textit{CPI-U, All Items}_{base}}$

As an example, the truck VOT for April 2021 (CPI-U, All Items of 267.054) would be calculated using **Equation 4** below:

$$VOT_{truck,\,April\ 2021} = \$30.75 \times \frac{267.054}{256.394} = \$32.03/\mathrm{hr}$$

The Maryland wage rates will be reviewed and updated periodically (every 3 to 5 years) to maintain the most current base information for the calculations. For the interim years, using the CPI-U to factor values will provide a reasonable estimate of wage rates at the time of each LOPB calculation. It should be noted that the availability of the wage rate data tends to lag behind the CPI-U data. Therefore, using the CPI-U is preferred over directly obtaining the wage rate from the BLS website for each LOPB calculation.

Operating Costs

Operating costs include all costs associated with owning a vehicle, including fuel costs, maintenance, tires, insurance, and depreciation. The presence of a work zone can increase the operating costs for road users if the work zone increases the required distance to travel (via a detour), the number of required vehicle stops and starts, or the time spent idling in a work zone queue. This section of the user guide discusses the user costs associated with increased distance, increased stops, and increased idling. The LOPB Spreadsheet only computes operating costs associated with extra distance traveled and extra stops if a signed detour route is implemented. While it is likely that some motorists will voluntarily detour around a work zone, it is difficult to accurately predict the percentage of vehicles that would divert or predict the specific routes they would use.

Increased Distance

When a work zone closes a roadway and a detour is required, road users incur additional operating costs due to the extra distance traveled around the work zone. To quantify this impact, the LOPB Spreadsheet uses the current IRS mileage rate for calculating automobile and truck operating costs. As an example, the 2021 IRS mileage rate is $0.56 per mile. A review of the AAA “Your Driving Costs” brochure confirmed that the IRS rate is a reasonable approximation of average driving costs per mile.

Increased Stops

The operating costs associated with making additional stops along a detour route, either at a red traffic light, a stop sign, or to perform a turning maneuver, are already factored into the IRS mileage rate for automobiles discussed in the previous section. However, since there is no known equivalent IRS mileage rate for trucks, the LOPB Spreadsheet computes additional operating costs for trucks resulting from additional stops along the detour route. The operating costs for trucks traveling around a work zone on a detour are therefore the sum of the IRS mileage rate for automobiles plus the net truck stopping cost rate.

The net truck stopping cost is derived from values reported in *NCHRP Report 133* and consists of the truck stopping cost minus the auto stopping cost. The average truck stopping cost is calculated by averaging stopping costs for four scenarios: $0.154 per stop and $0.176 per stop for single-unit trucks with an initial speed of 40 mph and 45 mph, respectively, and $0.653 per stop and $0.761 per stop for combination trucks with an initial speed of 40 and 45 mph, respectively, as reported in Table 12 of Chapter 2 of the 2010 *USDOT FHWA Work Zone Road User Costs – Concepts and Applications* publication, adjusted from the NCRHP Report 133. The average auto stopping cost is calculated from 2010 values reported in Chapter 2, Table 12 of the *USDOT FHWA Work Zone Road User Costs – Concepts and Applications*, which were adjusted from *NCHRP Report 133*. The average auto stopping cost was calculated as the average of the stopping cost of $0.0714 per stop for passenger cars with an initial speed of 40 mph and $0.0841 per stop for an initial speed of 45 mph. The auto stopping cost is only used to calculate the net truck stopping cost and will not be used for other calculations. As noted above, this cost is already included in the IRS mileage rate for automobiles.

Because both the truck and auto stopping costs are from 2010, the 2010 CPI-U, Transportation of 194.079 is used to adjust the net truck stopping cost to the present year. The net truck stopping cost is calculated below in **Equation 5:**

Equation 5:

$$Net\ Stopping\ Cost_{truck,\ present} = (Avg\ Stopping\ Cost_{truck,\ base} - Avg\ Stopping\ Cost_{auto,\ base}) \times \frac{CPI\text{-}U, Transportation_{present}}{CPI\text{-}U, Transportation_{base}}$$

As an example, an April 2021 (CPI-U, Transportation of 222.547) net truck stopping cost was calculated by substituting the above average truck and auto stopping costs into **Equation 5** as shown below:

$$Net\ Stopping\ Cost_{truck,\ April\ 2021} = \left(\frac{\$0.154 + \$0.176 + \$0.653 + \$0.761}{4} - \frac{\$0.0714 + \$0.0841}{2}\right) \times \frac{222.547}{194.079} = \$0.41/\text{stop}$$

Increased Idling

Increased idling costs are the additional vehicle operating costs associated with idling the engine of a stationary vehicle in work zone queues involving temporary signals/flaggers. Increased idling costs are not included in work zone queues involving lane closures because vehicles are assumed to be moving slowly, but not completely stopped. The LOPB Spreadsheet uses idling rates derived from idling costs reported in Chapter 2, Table 12 of the 2010 *USDOT FHWA Work Zone Road User Costs – Concepts and Applications* publication, adjusted from *NCRHP Report 133*.

With a base year 2010 cost of $0.94 per hour, the present year increased auto idling cost is adjusted using the present year CPI-U, Transportation as shown in **Equation 6** below:

$$\textbf{Equation 6: } Idling\ cost_{auto,\,present} = Idling\ cost_{auto,\,base} \times \frac{CPI\text{-}U,\ Transportation_{present}}{CPI\text{-}U,\ Transportation_{base}}$$

The auto idling cost for April 2021 is calculated as an example by substituting applicable values into **Equation 6** as shown below:

$$Idling\ cost_{auto,April\ 2021} = \$0.94 \times \frac{222.547}{194.079} = \$1.08/\mathrm{hr}$$

The truck idling cost is calculated similarly to the auto idling cost, as shown below in **Equation 7**. To simplify future calculations, the 2010 idling costs for single unit and combination trucks were averaged. The idling costs of \$1.04 per hour for single-unit trucks and \$1.12 per hour for combination trucks were reported in Chapter 2, Table 12 of the *USDOT FHWA Work Zone Road User Costs – Concepts and Applications* publication, adjusted from *NCRHP Report 133*.

$$\textbf{Equation 7: } Idling\ cost_{truck,\,present} = Idling\ cost_{truck,\,base} \times \frac{CPI\text{-}U, Transportation_{present}}{CPI\text{-}U,\ Transportation_{base}}$$

The truck idling cost for April 2021 is calculated as an example by substituting applicable values into **Equation 7** as shown below:

$$Idling\ cost_{truck,\,April\ 2021} = \frac{\$1.04 + \$1.12}{2} \times \frac{222.547}{194.079} = \$1.24/\mathrm{hr}$$

Crash Costs

Crash costs may be developed on a case-by-case basis independent of the LOPB Spreadsheet at the project team's discretion. The LOPB spreadsheet allows input of user-developed crash costs. If crash costs are used, the user must attach documentation of the assumptions and calculations used to determine crash costs. Because recent, local, and reliable crash data are not always readily available, the default option used in LOPB analysis is to assume negligible crash costs ($0).

Therefore, the final LOPB calculations will be based on two primary factors – delay costs and operating costs.

Cost Summary

The below table summarizes costs used in the LOPB Spreadsheet, the module they are used in, and the year the cost is based on.

Cost	Applicable Modules	Base Data Year
Auto delay cost	Full Closure with Detour, Temporary Signal/Flagger, Lane Closure, Lane Closure with Signals	2020
Truck delay cost	Full Closure with Detour, Temporary Signal/Flagger, Lane Closure, Lane Closure with Signals	2020
Auto increased distance cost	Full Closure with Detour	Present year
Truck increased distance cost	Full Closure with Detour	Present year
Truck increased stopping cost	Full Closure with Detour	2010
Auto increased idling cost	Temporary Signal/Flagger	2010
Truck increased idling cost	Temporary Signal/Flagger	2010
Crash costs (optional)	Full Closure with Detour, Temporary Signal/Flagger, Lane Closure, Lane Closure with Signals	Varies

C. USING THE PROGRAM

This section of the user guide provides instructions for using the LOPB Spreadsheet and determining the appropriate input values.

Opening the Program

The LOPB Spreadsheet is a Macro-Enabled Excel file. As a security measure, the default setting in Microsoft Excel is to disable macros. Macros can be enabled by clicking the proper button when prompted, such as the “Enable Content” or “Enable Macros” buttons shown in Figure 1 below.

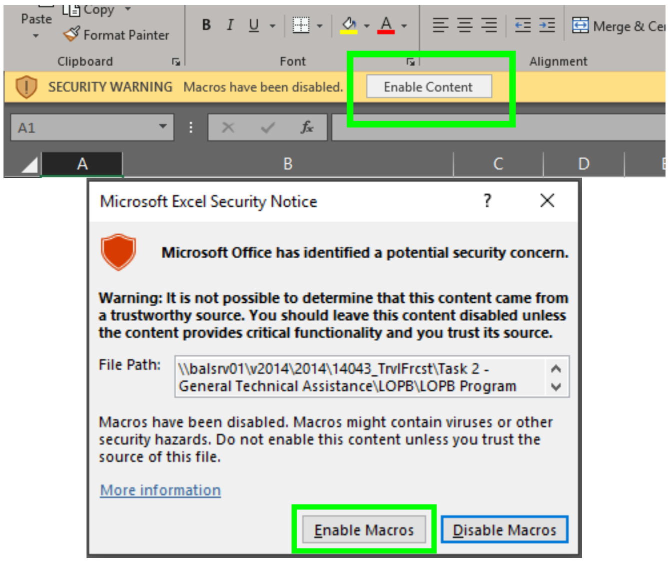


Figure 1: Buttons to enable macros

Once the LOPB Spreadsheet is open and macros are enabled, the “Save As” feature should be used to save a new copy of the file for the analysis.

Starting an Analysis

Throughout the LOPB Spreadsheet, users should follow the steps shaded in gray and enter information in the cells shaded in blue. Users should ensure information is entered in the correct units as prompted. There are various buttons to click to complete the analysis and navigate through the spreadsheet. These buttons are discussed in more detail throughout this section of the user guide.

When opening the LOPB Spreadsheet, the “Start” tab is visible as shown in Figure 2 below.

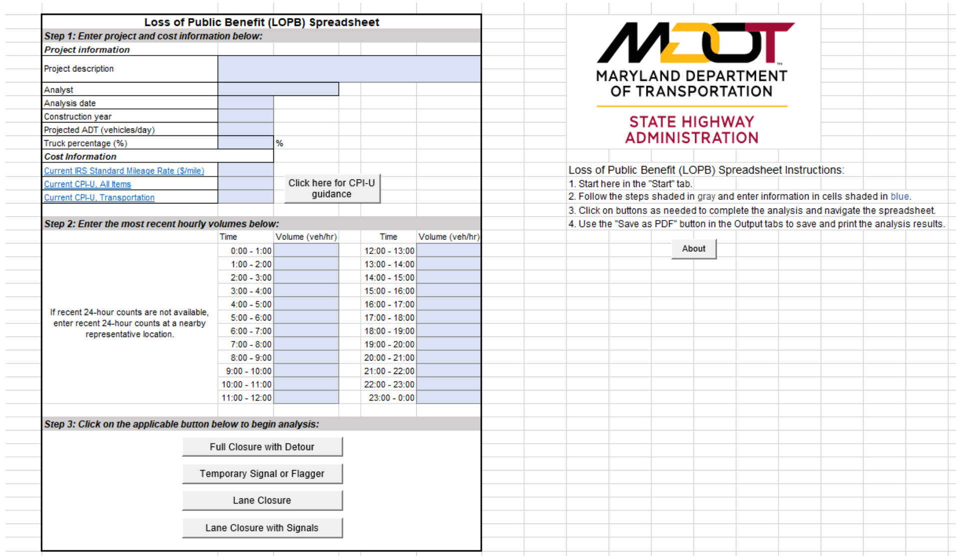


Figure 2: LOPB Spreadsheet "Start" tab

As discussed above, enter project and cost information in the shaded blue cells. Note that the projected average daily traffic (ADT) value entered should be the estimated ADT during the year of construction. Also, the truck percentage should be a whole number (e.g. if a roadway truck percentage is 5 percent, type in “5” not “0.05”). Cost information is entered to calculate analysis year costs for delay and operating costs. The current IRS standard mileage rate should be entered in dollars (e.g. if the current rate is 56 cents per mile, enter “0.56”). Two CPI-U values are required: the CPI-U for all items and the CPI-U for transportation. Click the hyperlinks to visit the BLS website to view tables showing the latest available values. For both CPI-U values, use the most recent month’s unadjusted index as shown in Figure 3 below, which can also be viewed by clicking the “Click here for CPI-U guidance” button.

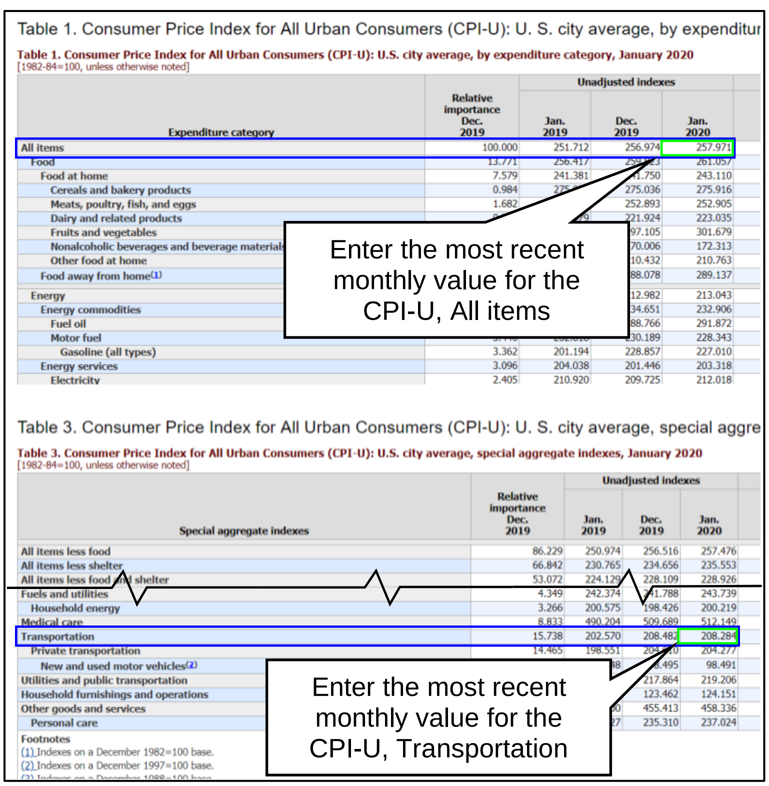


Figure 3: BLS CPI-U tables

If recent 24-hour counts are not available, the user should enter recent 24-hour counts from a nearby representative location. Nearby representative locations can be used because 24-hour counts are used to obtain hourly percentages and weighting factors that are applied throughout calculations. It is the hourly distribution of the 24-hour counts that is used, not the exact hourly volumes.

After the project and cost information is entered, click on the applicable button to proceed with the desired analysis module. Each module is discussed below.

Module 1 – Full Closure with Detour

The Full Closure with Detour module determines the costs of additional delay, distance, and truck stops associated with the detour. The module may use one of three travel time data sources: Google travel times, travel time runs, and simulation models. Click on the option button to specify the data source used in the analysis. The user decides which travel time data source is best suited for the project. Google travel times are quick and easy to obtain, while still being reliable. Travel time runs are also accurate but may not be possible due to schedule or budget constraints. Simulation models should be used when detour route travel times are anticipated to significantly increase from current conditions due to additional detoured traffic using the route. If the detours for the two travel directions are different, each direction should be run separately and the values in the “Start” tab (ADT, truck percentage, and 24-hour volumes) should be specific to the analysis direction.

All three data sources require the number of stops, total length, and travel times for the closure route and the detour route. Instructions for determining these values are below:

- Number of stops: Use engineering judgement and information such as the number of signalized intersections, stop-controlled intersections, and turns to estimate the number of stops vehicles will make for each route.
- Total length: Use Google Maps to determine the distance vehicles will travel for each route following the below steps:
    - Right-click on the start point of the closure/detour and click “Directions from here”
    - Right click on the end point of the closure/detour and click “Directions to here”
    - Google Maps will show the travel distance between the two points. The default route is the fastest, which is typically the closure route. An example is shown below in Figure 4a.
    - To determine the travel distance of the detour route, click a point on the blue highlighted closure route and drag it to the detour route. An example is shown below in Figure 4b.

a) b)

Figure 4a) Example closure route on Google Maps, b) Example detour route on Google Maps

- AM peak, PM peak, and off-peak travel times:

- For the Google travel time method: Click on the “Leave now” dropdown, select “Depart at”, and change the time to match each of the three time periods as shown below in Figure 5.

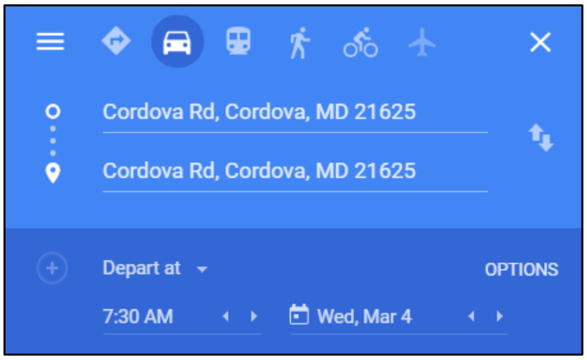


Figure 5: Modifying departure time in Google Maps to obtain time-specific travel times

- For the travel time runs and simulation model methods: Enter the obtained travel times for the respective data sources. If the travel time during one of the time periods was not obtained, use the Google travel time method to do so.

When all information has been entered, click on the “Finish” button to view the Full Closure with Detour analysis output. The output is opened in a new tab and displays the information used and calculations performed to determine the daily LOPB. Click the “Save as PDF” button to save the file as a PDF.

Module 2 – Temporary Signal / Flagger

The Temporary Signal/Flagger Module determines the costs of additional delay and idling associated with the temporary signal or flagger. It is used when construction requires two-way traffic to share a single lane and alternate directional vehicle right-of-way on the route.

The LOPB Spreadsheet requires delays to be estimated using a simulation model created for each of the three analysis periods. Because simulation models can easily be modified for different periods, all three analysis period delays are required inputs.

The first step is to create and run the simulation models for the AM peak, PM peak, and off-peak periods. The off-peak period is the hour with the median volume and is shown along with the AM and PM peak periods in Step 1. Step 1 requires the user to enter the volumes used in the simulation models. Both the peak and non-peak direction volumes for the three analysis periods are required.

The user may choose to use the included Synchro/SimTraffic template file and comma-separated (CSV) files to expedite the simulation model creation process. The LOPB Spreadsheet contains a step that creates CSV files to quickly model the Synchro/SimTraffic template file as the roadway being analyzed. A screenshot of the template file is shown below in Figure 6.

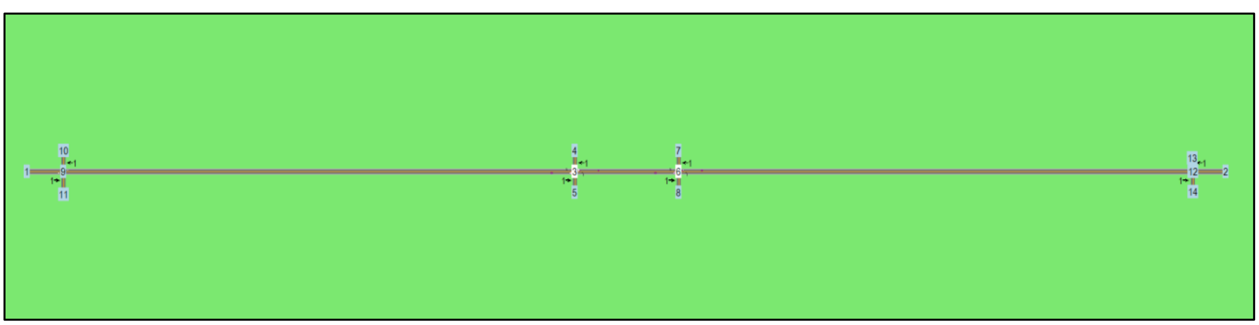


Figure 6: Temporary Signal or Flagger Synchro/SimTraffic template file

The file models a temporary signal or flagger operation by creating two signalized intersections controlled by a cluster traffic signal. The space between the intersections represents the work zone and the traffic signals represent the temporary signals or flagger. The two unsignalized intersections at the edges of the template roadway are included to mark the beginning and end of the arterial segment when reporting delays. If the user decides to use the template file, they should follow the below steps:

1. Save the LOPB Spreadsheet, Synchro/SimTraffic template files, and seven template CSV files in the same folder.
2. Enter information in LOPB Spreadsheet Step 1a to modify the default parameter values in the provided template file. Notes on certain parameter values are below:
    a. All information entered in Step 1a can be changed in Synchro/SimTraffic after being imported from the CSV files.
    b. The approach length should be long enough to accommodate the expected queue length. If the queue length exceeds the approach length, the reported delays will not include vehicles that were unable to enter the network.
    c. The all-red time should be long enough to clear all vehicles from the shared right-of-way. In areas with high truck percentages, consider trucks' increased acceleration time.
    d. The default minimum and maximum green times are equal to model pretimed signals. To model signals on minimum recall, the minimum initial (minimum green time) may be decreased.
3. Click the "Generate CSV files" button and select the folder the CSV files are saved in. This will create 7 CSV files to modify the Synchro/SimTraffic file to model the roadway being analyzed. These files are the layout file (for the geometry), the lanes files (for lane information in each of the analysis periods), and the phasing files (for the signal phasing information in each of the analysis periods). Multiple Excel windows will open and close, but the process will be complete when the below popup message (Figure 7) is displayed. It is noted that these CSV files were designed for Synchro 10, and other versions of Synchro may not read the CSV files correctly.

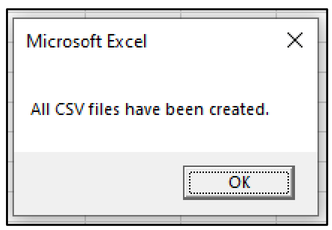


Figure 7: Message box at end of Temporary Signal or Flagger CSV files creation

4. Open the Synchro template file and save the file as the AM, PM, or off-peak analysis period. Click the "Transfer" tab, then click "Read/Write", then click "UTDF Layout" (see Figure 8).

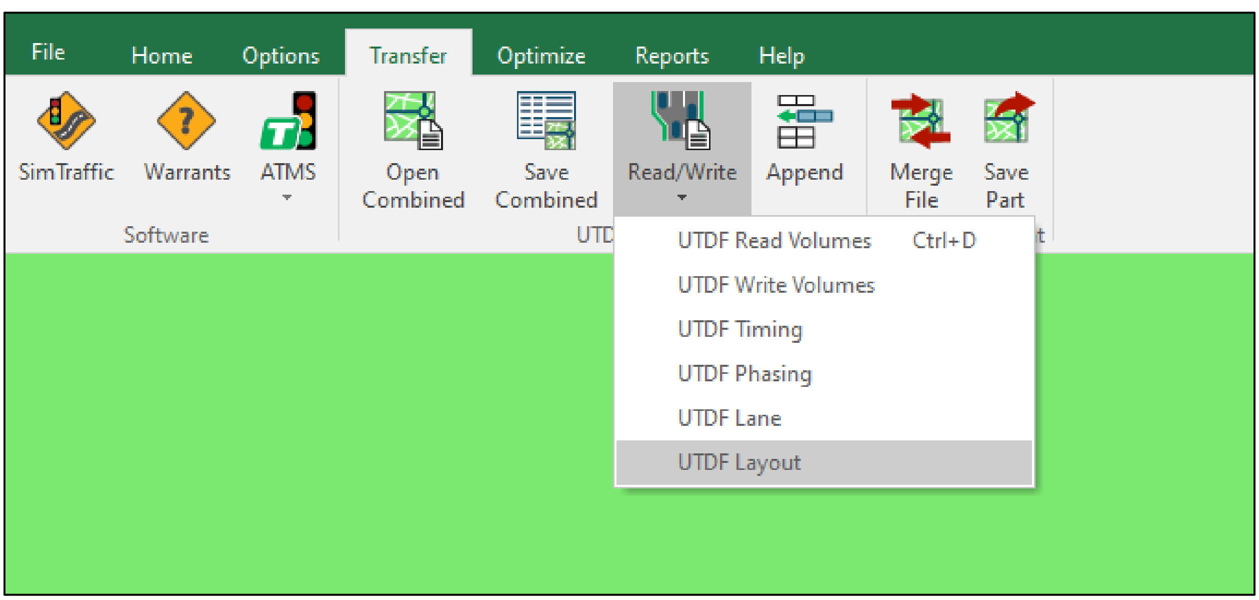


Figure 8: Temporary Signal or Flagger CSV file transfer steps

5. Select the “LAYOUT” CSV file and click “Read”.
6. In the same popup window, click on the “Lane” tab, select the corresponding analysis period’s lane CSV file (either LANES_AM, LANES_PM, or LANES_OFF), and click “Read”.
7. In the same popup window, click on the “Phasing” tab, select the corresponding analysis period’s phasing CSV file (either PHASING_AM, PHASING_PM, or PHASING_OFF), and click “Read”.
8. The information entered in Step 1a will now be reflected in the Synchro model. Close the popup window and make any further adjustments if necessary.
9. Open SimTraffic and ignore the error regarding a reference phase not in use (this error is a result of using cluster signals to model flagging/temporary signal operations in the work zone).
10. Click “Multiple Runs” and run 5 simulations.
11. After the simulations are finished running, create an Arterial Report by clicking on the “Reports” tab, clicking “Create Reports”, checking the “Arterial Report” box, and selecting the analysis roadway. Ensure the “Multiple runs” box is checked and click “Print” to print or save a PDF of the arterial report. Arterial reports output the peak and off-peak direction delays.

Step 2 requires the user to input the peak and non-peak direction delays, which are obtained from the Arterial Reports.

When all information has been entered, click on the “Finish” button to view the Temporary Signal/Flagger analysis output. The output is opened in a new tab and displays the information used and calculations performed to determine the daily LOPB. Click the “Save as PDF” button to save the file as a PDF.

Module 3 – Lane Closure

The Lane Closure module calculates LOPB per direction resulting from lane closures on freeways by using freeway work zone capacity estimation methods from the HCM. The HCM does not contain methods to estimate multilane highway work zone capacity. If a multilane highway must be analyzed, the user should determine if traffic signals impact traffic operations. If there are no traffic signals impacting operations, the multilane highway should be analyzed as a freeway. If traffic signals do impact operations, the Lane Closure with Signals module should be used as described in the next section, “Module 4 – Lane Closure with Signals.” If a multilane highway without traffic signals has a free-flow speed less than 55 mph, the free-flow speed should be entered as 55 mph.

The Lane Closure module determines the costs of queue delay associated with a work zone lane closure. The module calculates costs for one direction of travel only. If there are lane closures in both directions, the module must be run twice and the values should be summed to calculate the total LOPB. The module requires information regarding normal (non-work zone) conditions in Step 1, the hours of work zone operation in Step 2, work zone information in Step 3, and capacity information in Step 4.

To determine the work zone delay, the normal and work zone capacities must be estimated. In Step 4, the user can select from three options to estimate the capacities: HCM 2016 methodology, HCM 2010 methodology, or a manual input. Guidance for selecting a capacity estimation methodology is below:

- Use HCM 2016 methodology if there is sufficient work zone information for the required inputs.
- Use HCM 2010 methodology to complete a quick analysis or if there is insufficient work zone information.
- Use the manual input methodology if either HCM methodology will not accurately model the work zone.

If the free-flow speed entered in Step 1 cannot be field-measured, it should be estimated using the same methodology used to estimate the capacity in Step 4. Instructions for estimating the free-flow speed can be found in Chapter 12 (Equation 12-2) and Chapter 10 (Equation 10-10) of the 2016 HCM and Chapter 11 (Equation 11-1) of the 2010 HCM. If the required information is not available to estimate free-flow speed using HCM methodology, it may be estimated based on the posted speed limit.

The HCM 2016 capacity estimation method requires additional non-work zone and work zone inputs:

- Non-work zone input

    - Capacity adjustment factor (CAF): adjustment for weather condition (see Exhibit 11-20; use default value of 1.00 for non-severe weather) and level of driver familiarity (see Exhibit 26-9; use default value of 1.00 when all drivers are familiar). Incident CAFs are not used.
- Work zone inputs
    - Barrier type: Concrete/hard barrier separation or cone, plastic drum, or other soft barrier separation.
    - Area type (f_{at}): Urban areas or rural areas.
    - Lateral distance (f_{lat}): Lateral distance from the edge of travel lane adjacent to the work zone to the barrier, barricades, or cones (0 to 12 ft).
    - Daylight/night (f_{DN}): Daylight or night. If the work zone has a 24-hour lane closure, the variable should be set to Daylight because the majority of traffic volumes occur during daylight hours.

If the user does not have the above values, they may use the default values where applicable or use one of the other capacity estimation methods. HCM 2016 methodology is not recommended for use on mountainous terrain; for roadways on mountainous terrain, use one of the other capacity estimation methods.

The LOPB Spreadsheet provides delays under normal conditions (e.g. delays due to recurring congestion) and delays under work zone conditions (e.g. delays due to both recurring congestion and the work zone). The work zone delay used in LOPB calculations is calculated as the work zone conditions delay minus the normal conditions delay. This is done so delay caused by recurring congestion is not included in the LOPB calculation, while the LOPB calculation does include delay caused by queues that remain after the work zone is removed. These delays are shown in the Lane Closure Output tab in the “Delay Costs” section.

The Lane Closure module hourly queue calculations begin at 5AM instead of 12AM to account for overnight closure queues that spill over beyond 12AM. In most cases, the 5AM hour will not have queues present. If queues are still present at 5AM, a popup message will be shown and the user should consider a different maintenance of traffic alternative.

The Lane Closure module can calculate the LOPB for two- and three-lane freeway work zones without lane closures (i.e. shoulder closures, crossovers, lane shifts, etc.) when using the HCM 2016 capacity estimation method. If this analysis is desired, the number of work zone lanes in Step 3 should be set equal to the number of normal lanes in Step 1.

When all information has been entered, click on the “Finish” button to view the Lane Closure analysis output. The output is opened in a new tab and displays the information used and calculations performed to determine the daily LOPB. Click the “Save as PDF” button to save the file as a PDF.

Module 4 – Lane Closure with Signals

The Lane Closure with Signals module should be used to determine the LOPB per direction on multilane highways with traffic signals. As with the Lane Closure module, the Lane Closure with Signals module calculates costs for one direction only. If there are lane closures in both directions, the module must be run twice and the values should be summed to calculate the total LOPB. Synchro/SimTraffic models should be created for work zone (lane closure) and non-work zone (normal) conditions. Models should be created for the AM peak, PM peak, and off-peak analysis periods. The off-peak period is the hour with the median volume and is shown along with the AM and PM peak periods in Step 1. Although there are six simulation models to create, they can be quickly created by modifying the volumes and/or open lanes from the first created file. The user should then generate Arterial Reports and enter the travel times in Step 2.

When all information has been entered, click on the “Finish” button to view the Lane Closure with Signals analysis output. The output is opened in a new tab and displays the information used and calculations performed to determine the daily LOPB. Click the “Save as PDF” button to save the file as a PDF.